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Japanese Published Unexamined Patent Application (A) No. 02-22457, published January 25, 1990; Application Filing No. 63-173455, filed July 11, 1988; Inventor(s): Masao Noma et al.; Assignee: Shinkoo Precision Machinery and Equipment, Inc.; Japanese Title: Device for Forming Conductive, Transparent, and Thin ITO Films

DEVICE FOR FORMING
CONDUCTIVE, TRANSPARENT, AND THIN ITO FILMS

CLAIM(S)

A device for forming a conductive, transparent, and thin ITO film comprising the following: a vacuum tank; an evaporation source consisting of ITO pellets evaporated by an impact of electron beam emitted from an electron gun positioned in said vacuum tank; a holding means positioned at a specific distance from the evaporation source, holding a substrate to be processed, and equipped with a heating means of heating the substrate to about 2000C – 3000C; an ionization electrode, which is positioned between said evaporation source and the substrate, and to which positive voltage is charged using the potential of evaporation source as a reference voltage; a thermal electron emitting filament, which is positioned between said evaporation source and the ionization electrode, and to which negative

voltage is charged using the potential of said evaporation source as a reference voltage; a nozzle for introducing an O_2 gas of 1×10^{-4} Torr – 10×10^{-4} Torr into said vacuum tank; a control means of monitoring the thickness of the thin film being formed and of controlling said electron gun power to keep the film formation rate at the prescribed value.

DETAILED DESCRIPTION OF THE INVENTION

(Field of Industrial Application)

The present invention pertains to a device for forming a conductive, transparent, and thin ITO (mixture of indium oxide In_2O_3 and of Zinc oxide SnO_2) film, particularly to the device for forming an arc discharge type conductive, transparent, and thin ITO film suited for use in forming a display panel electrode having a high light transmission rate.

(Prior Art)

The prior art conductive, transparent, and thin ITO film used for a liquid crystal display panel was formed by a vapor deposition, ion vapor deposition, or a sputtering method. The conductive, transparent, and thin ITO film formed by a widely used sputtering method had $3 \times 10^{-4} \Omega/cm$ resistivity and 85% light transmission rate.

(Problems of the Prior Art to Be Addressed)

In recent years, liquid crystal display panels are moving towards a larger and larger dimension. Along with this trend, a wire length of electrodes and electrode connection circuits are getting longer. Accordingly, it has come to be necessary to develop a conductive, transparent, and thin ITO film having lower resistivity, e.g., $2 \times 10^{-4} \Omega/\text{cm}$ or less, without reducing the light transmission rate. The conductive, transparent, and thin ITO film formed by the aforementioned prior art sputtering method could not be used for a liquid crystal display panel with a large dimension for its resistivity being $3 \times 10^{-4} \Omega/\text{cm}$ and its light transmission rate being 85%. Even an ion vapor deposition method is used, it was impossible to form a conductive, transparent, and thin ITO film having the resistivity and light transmission rate usable enough for wiring the electrodes of liquid crystal display panel with a large dimension.

(Means to Solve the Problems)

The device for forming a conductive, transparent, and thin ITO film in the present invention comprises: a vacuum tank, an evaporation source consisting of ITO pellets housed in a crucible and positioned inside the vacuum tank, an electron gun for radiating electron beam to said evaporation source to evaporate the source, an ionization electrode to which positive voltage is charged and which is positioned at the upper section of said

evaporation source, and a thermal electron emitting filament to which negative voltage is charged and which is positioned between said evaporation source and ionization electrode. Inside the vacuum tank, is positioned the substrate holding means 14 equipped with a heater for heating the substrate to be processed, and by said holding means 14, said substrate is held to oppose to said vapor source. Near the substrate to be processed, is installed a film thickness monitor for monitoring the thickness of the thin film being formed. By controlling the power of electron gun by the signal from the film thickness monitor, the evaporation particle generation rate is controlled to control the rate of depositing the evaporated particles, in other words, to keep a thin film formation rate at a constant level. Also, inside the vacuum tank, is installed a nozzle for introducing an oxygen (O_2) gas.

(Operation)

In the film forming device for forming said conductive, transparent, and thin ITO film, a vacuum pump is operated to create a vacuum at the prescribed level, $10^{-5} - 10^{-7}$ Torr. Then, a proper level of positive voltage between 10 V and 100 V is charged into the ionization electrode using the vapor source voltage as a reference. Also, a proper level of voltage between 0 V and 2,000 V is likewise charged into the substrate to be processed and, at the same time, said substrate is heated to a temperature between 2000C and

3000C by operating the heater of said holding means. At this point, once the electron beam is scanned over the ITO pellets of the evaporation source by operating the electron gun, the ITO is evaporated, and the evaporated particles are directed to the substrate to be processed. These evaporated particles are emitted from the thermal electron emission filament, and accelerated by the positive voltage charged into the ionization electrode, in the O₂ gas supplied from the gas nozzle; they are further ionized by the electron with increased energy, directed to the substrate, and deposited on its surface. In this case, charging the negative voltage into the thermal electron emitting filament increases the potential difference between the said filament and the ionization electrode, making the thermal electron emission easy and improving the ionization effect of O₂ gas and of evaporated ITO particles. Also, said thin film formation rate is controlled at the prescribed constant value by monitoring the thin film being formed on the substrate and by controlling the power of electron gun by the output signal from monitoring.

(Embodiment)

The present invention is explained more specifically below with reference to the figures. In the figures, 2 indicates the vacuum tank, and a vacuum is created to the level of 10^{-5} - 10^{-7} Torr in this tank by the vacuum pump (not shown) connected to the air exhaust port 4. On the bottom section

of this vacuum tank 2, is positioned a crucible 6 in which ITO pellets 7 as the evaporation source are housed. The weight ratio of ITO pellets 7 is In_2O_3 : $\text{SnO}_2 = 95 : 5$, and the pellet is a sinter with a 50 mm diameter and a 10 mm height 10. The composition ratio of ITO pellets and the size of pellet can be properly changed by properly selecting the size of the substrate to be processed, the resistivity of the thin film to be formed, and the light transmission rate. In the figure, 8 indicates the electron gun, which impacts the ITO pellets 7 with its electron beam 10 while simultaneously scanning the pellet surfaces to evaporate the ITO. At this time, the crucible 6 is kept at grounding potential. In the upper section of vacuum tank 2, the substrate 14 held by holding means 12 to oppose to the ITO pellets 7 as the evaporation source is positioned with the distance H_1 between them (for example, 150 mm to 700 mm, more preferably 400 mm). The substrate to be processed is kept at 0 V in this example. The holding means 12 is also used as a heater for heating the substrate 14 to 2000C – 3000C and is energized by an alternate current power source 17.

At the position H_2 (5 mm – 100 mm, preferably 60 mm) at an angle from the ITO pellets 7 above the crucible, is installed a sheet-formed ionization electrode 18, which is kept at +10 V - +100 V, preferably at +50 V by the ionization power source 20. Between the evaporation source 7 and the

ionization electrode 18, is installed a tungsten filament 22 for thermal electron emission, and this thermal electron emitting filament is heated to nearly 2,000°C at which it can emit the thermal electron by the AC power source 24 of 10 – 100 V capacity. This thermal electron emitting filament 22 is biased to negative voltage of –20 V – 150 V, preferably –30 V by the bias power source 26. In the figures, 28 indicates the O₂ gas introducing nozzle, and the O₂ gas is introduced into the vacuum tank 2 to the level of $1 \times 10^{-4} - 10 \times 10^{-4}$ Torr; in this example, to the level of 5×10^{-4} Torr. In the figures, 30 indicates a crystal oscillation type film thickness monitor, which monitors the thickness of the film being formed on the substrate 14 and generates an electrical signal. This electrical signal is feedback to the driving power source of the electron gun 8 and controls the electron gun power so that the rate of the ITO particle deposition on the substrate 14, i.e., the film formation rate, remains at a constant value. For example, although not shown in the figures, the electrical signal controls the O₂ gas supplied from the mass flow controller through the nozzle 28 so that the pressure remains constant in the vacuum tank.

(Advantage)

By using the parameters, 5×10^{-4} Torr for the O₂ gas pressure, +50 V for the voltage of ionization electrode 18, 8A for the current, and –30 V for

the voltage of thermal electron emitting filament 22, and by charging the 0 V voltage to the substrate while keeping it at 2000C – 3000C, the thin ITO film with resistivity $1.1 \times 10^{-4} \Omega \text{ cm}$ and with the light transmission 74.9% was formed. Moreover, when the film was formed using the same parameters as those of the above and setting 0 V for the thermal electron emitting filament 22, the resistivity of the ITO film was $1.5 \times 10^{-4} \Omega \text{ cm}$ and the light transmission rate was 74.9%. Thus, it was confirmed that raising the emitted electron energy by charging the negative voltage into thermal electron emitting filament forms an ITO film with lower resistivity and higher light transmission rate. Since the substrate was heated to 3500C – 4000C before the film formation in the prior art device, it was necessary to use the substrate that can tolerate a high heat of 4000C or higher, and it took long time for raising and lowering the temperature of the substrate, causing a problem to production yield. With the device of the present invention, however, the temperature of the substrate can be at 2000C - 3000C, so the substrate with low heat-resistance can be used, relative to that for the prior art device, and therefore one patch cycle is shortened, improving the productivity.

As explained above, by the device of the present invention, a thin ITO film with resistivity $2 \times 10^{-4} \Omega \text{ cm}$ or lower and with light transmission rate

85% or higher can be manufactured. Therefore, a thin ITO film with a thickness 2,000 Å, light transmission rate 90% or higher, and resistivity 10 Ω cm or less can be formed as a thin film for a liquid crystal display panel with a large dimension.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 shows a schematic diagram of the profile of the device for forming the conductive, transparent, and thin ITO film. Fig. 2 shows planar view of the vacuum tank indicating the positional relationship of the components, such as the electrode and evaporation source, in the vacuum tank.

2... vacuum tank

7...evaporation source (ITO pellets)

8...electron gun

12...holding means

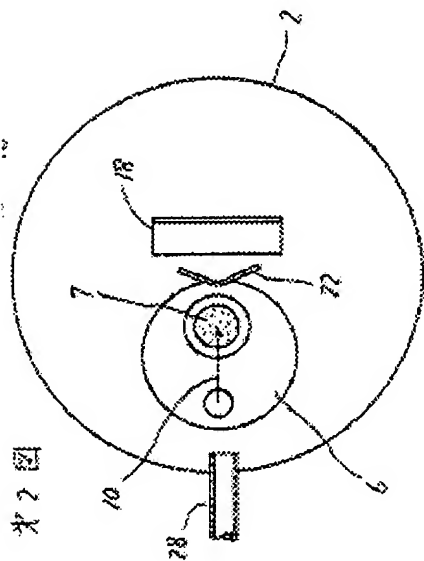
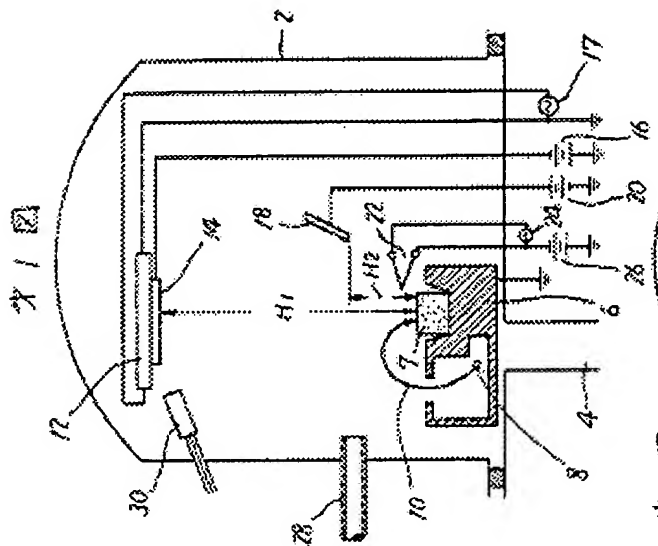
14...substrate

18...ionization electrode

22...thermal electron emitting filament

28...O₂ gas introduction nozzle

30...film thickness monitor



Translations
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